CIRCULAR No. 462 FEBRUARY 1938

UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D. C.

LOW TEMPERATURE AS A POSSIBLE MEANS OF CONTROLLING THE CIGARETTE BEETLE IN STORED TOBACCO

By M. C. Swingle, *associate entomologist, Division of Control Investigations, Bureau of Entomology and Plant Quarantine*[1]

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INTRODUCTION

The cigarette beetle (*Lasioderma serricorne* F.) is an important pest of cured tobacco, causing severe damage to unmanufactured tobacco as well as to manufactured tobacco products, such as cigars and cigarettes. The feeding by the larvae makes the leaves unfit for manufacturing purposes and the cigars unsalable. Then, too, although responsible for little actual damage, the presence of the other stages of the beetle in the product is objectionable.

The most common method of control at present is fumigation, which is applied either in tight rooms at atmospheric pressures or in chambers under partial vacuum. The latter method gives very good results but requires a great deal of labor in moving the stock to and from the fumatorium. In an effort to simplify the problem of control, some form of cold storage was suggested as a possible means of combining storage with the control of insects. It is doubtful if much of the huge stock of tobacco now held in storage could economically be held under refrigeration. It is possible, however, that some of the more expensive grades could be so stored, or that small-scale manufacturers could use the method to hold their working stock free from insect infestation.

[1] The cooperation afforded by W. D. Reed and E. M. Livingstone, of the Richmond, Va., laboratory of the Bureau of Entomology and Plant Quarantine, is gratefully acknowledged. Further acknowledgment is made to the Bureau of Plant Industry of the U. S. Department of Agriculture for the use of the cold-storage facilities at Arlington Experiment Farm, to the Merchants Ice & Storage Co. of Richmond, Va., for furnishing space in their cold-storage plant, and to the P. Lorillard Co. and the American Tobacco Co. of Richmond for the loan of the tobacco used in the experiments.

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Runner[2] found that all stages of the cigarette beetle could be killed by exposure to temperatures of between 14° and 20° F. He found that eggs in cigars could be killed by a 1-day exposure to temperatures below 20°. Boxes of cigars infested by all stages of the beetle were completely disinfested by a 7-day exposure at an average temperature of 14°. All stages of the beetle were killed in a bale of cigar tobacco in a 28-day exposure at the same temperature. Powell[3] reports that only 57-percent mortality was obtained in eggs held for 20 days at a temperature of approximately 35°. Neither author endeavored to find the minimum exposure required to give complete control at any given temperature. In the work recorded in this circular an attempt was made to establish the minimum exposure for complete control at temperatures of 10°, 15°, 20°, 25°. 30°, 32°, 36°, and 40°.

OBTAINING STOCKS OF THE INSECT FOR THE EXPERIMENTS

All the insects were reared at Richmond, Va., by the tobacco insect laboratory of the Bureau of Entomology and Plant Quarantine and brought by rail or automobile to Takoma Park, Md., or Arlington, Va., where the tests were made. Although the insects can be reared on several different diets, whole corn meal has been found very satisfactory and is used almost exclusively at the Richmond laboratory. The stock formerly was reared in Petri dishes, but these have been displaced by pint fruit jars with tight muslin caps. The jar is half filled with corn meal tamped down to insure a firm surface on which the beetles can walk. Here the females lay their eggs, and the resulting larvae feed downward into the corn meal. The mature larvae pupate in the corn meal near the surface in small cells which they make by cementing meal dust about themselves.

The adults are collected from the top of the jar into a modified Erlenmeyer flask connected to a vacuum pump. With this apparatus the insects can easily be counted and picked up without injury. Larvae were obtained by first screening them from the corn meal and then collecting them in the vacuum flask. Pupae were collected in a similar manner but were allowed to remain in their cells throughout exposure and subsequent incubation. Removing them from the cells was not practical because of the probability of injuring them when breaking open the relatively hard shell. Eggs were obtained by confining several hundred adults in a Petri dish with two short pieces of tobacco stems, or midribs, about 1¼ inches long. The small white eggs were deposited in cracks in the stems, and they were exposed to the cold by placing these stems directly in the cold room without disturbing or even counting the eggs.

EFFECT OF LOW TEMPERATURES ON THE INSECT

METHODS USED IN THE EXPERIMENTS

The tests to determine the lethal exposure period were made in the cold-storage laboratory of the Bureau of Plant Industry, at

[2] RUNNER, G. A. THE TOBACCO BEETLE: AN IMPORTANT PEST IN TOBACCO PRODUCTS. U. S. Dept. Agr. Bull. 737, 77 pp., illus. 1919.

[3] POWELL, T. E., JR. AN ECOLOGICAL STUDY OF THE TOBACCO BEETLE, LASIODERMA SERRICORNE FABR., WITH SPECIAL REFERENCE TO ITS LIFE HISTORY AND CONTROL. Ecol. Monog. 1: 333–393, illus. 1931.

Arlington Experiment Farm, Arlington, Va. Here a number of rooms were available which could be held at fairly constant temperatures between 10° and 40° F. Tests were planned to be made at 5° intervals throughout this range with an extra series run at 32°.

Petri dishes were chosen as suitable containers for the insect material during exposure. The numbers of insects desired were counted out as described above and placed in a sufficient number of dishes that there would be no crowding. The dishes were then labeled for the periods of exposure and temperatures and placed in the cold rooms. Shortly thereafter the lids were removed from the dishes to allow for more rapid cooling. When the exposure time had expired, the dishes were removed and placed in a room with a constant temperature of 70° F., and a humidity of approximately 70 percent. Adults and larvae were examined and their mortality recorded after 2 and 5 days, pupae after 6 and 10 days, and eggs after 20 and 30 days. At first many of the tests were held for periods up to 3 months to check against any possible late recovery. No revival was ever noted, however, and as a matter of fact the tendency was toward an increased mortality among some of the weakened individuals.

THE RESULTS

A total of 19,595 eggs were exposed at 8 different temperatures between 10° and 40° F. These had been laid on short tobacco stems, as previously stated, and exposed in Petri dishes, from 200 to 400 eggs being used in each test. Complete mortality was obtained by a 1-hour exposure at 10° and a 3-hour exposure at 15°. At 20° and above the exposure time for eggs was measured in days, as shown in figure 1. This diagram shows the exposures required for absolute mortality at various temperatures, but it is possible to kill about 95 percent of the eggs with half the exposure necessary for a 100-percent mortality. Thus there is a possibility of obtaining a measure of economic control of the beetle in open warehouses where low winter temperatures prevail.

The tests on the larvae were made prior to those on the other stages and no facilities at a temperature of 10° F. were available at that time. One hundred full-grown larvae were placed in each Petri dish, and several dishes were used for each test. Figure 1 shows the results obtained on exposing 6,850 larvae. Sixty hours was required to obtain a complete kill at 15° as compared with 3 hours for the egg stage. At 20° the exposure for larvae was five times as long as for eggs, but at 25° the exposure was the same. In each graph the exposure period for 32° was the same as that for 30°, but above and below these points the period of exposure changes rapidly.

A total of 3,520 pupae were used in this series of tests. These were counted out some 50 to 75 to a dish and exposed without opening the thin pupal cells. From 6 to 10 days after exposure the cells were broken open and a check made of the number of pupae and their condition. Cells containing adults and larvae were discarded. It is evident from the graph that pupae were about as resistant as eggs to the lower temperatures, but above 25° F. they were slightly more resistant, and no complete kill was obtained above 36° although a 50-day exposure at 40° was tried. Pupae were killed in 1 hour at 10°, in 3 hours at 15°, and in 16 days at 36°. As in the case of the larvae and the eggs, the exposure period for complete mortality was the same for 32° as for 30°.

In tests with the adults, 200 newly emerged adults were placed in each Petri dish, and 1 or 2 such dishes used in each test. Considerably more variation in resistance among individuals was noted in the case of the adults than in the tests with the other stages. From 200 to 300 adults were necessary for a significant figure on mortality, whereas 100 larvae were sufficient to give a figure of approximately the same significance. The results obtained with a total of 15,485 adult beetles are also shown in figure 1. The adult was slightly

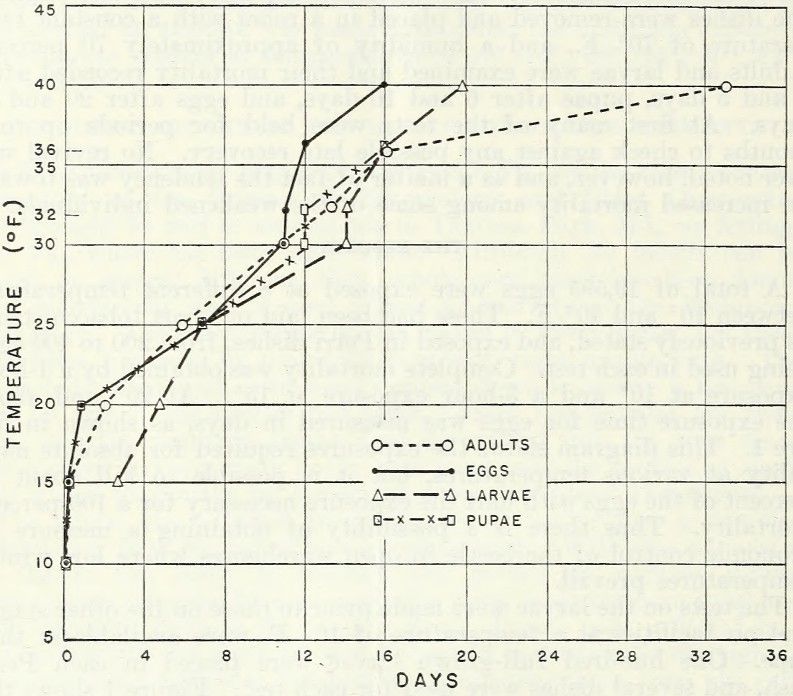

FIGURE 1.—Days of exposure required for assuring complete mortality of eggs, larvae, pupae, and adults of the cigarette beetle at various temperatures ranging from 15° to 40° F.

more resistant to the lower temperatures than the egg and pupal stages. At 10° a 1-hour exposure was lethal, but at 15° a 5-hour exposure and at 20° a 2-day exposure was necessary to produce complete mortality. In the case of the adults, in contrast to that of the eggs, larvae, and pupae, the exposure at 32° was 2 days longer than at 30°. An exposure of 33 days was required at 40°.

Of particular interest in the graphs shown in figure 1 is the position of the time-temperature points at temperatures of 30°, 32°, and 36° F. The time required to cause complete mortality in eggs is nearly the same for 30°, 32°, and 36°, only 1 day more being required to produce complete mortality at 36° than at 30°. In the next 4-degree rise in temperature, however, the time to produce complete mortality was increased 4 days. With larvae it requires 2 days longer at 36° than at 30° and 32° to effect complete mortality, whereas with pupae a 4-day longer exposure at 36° than at 30° or 32° is required to produce complete mortality. The positions of the points for the adult insect at 30°, 32°, and 36° are in contrast to those for the other stages, though it requires 17 days longer to effect complete mortality at 40° than at 36°. It seems evident from these results that death is produced, not from freezing nor from the crystallization of water in the insect, but from some physiological condition brought about by these low temperatures, and that the same effect may be produced in approximately the same time at various temperatures between 30° and 36°.

Some work was done on the freezing of the various stages of this insect, but lack of time prevented carrying this portion of the problem to completion. In the work done it was found that all stages of the insect were readily undercooled well below the freezing point. In some cases the insect would not begin to freeze until below 0° F.

Powell [4] reports a 57-percent mortality among eggs exposed for 20 days at a temperature of approximately 35° F. This is in contrast to the exposure time of 11½ days for complete mortality at 35° as shown in figure 1. In the present work an extremely wide fluctuation in resistance was found among individuals. The insects used in making these determinations were reared on corn meal at a temperature of 80° and a humidity of approximately 70 percent. Individuals reared under different conditions of temperature and humidity might show a difference in resistance to low temperatures. Checks made at 25° with insects reared on tobacco showed no significant difference in resistance between the individuals reared on the two diets. It was noted, however, in the tests on the undercooling point, that individuals reared in a relatively dry laboratory room generally had a very low undercooling point. It should also be pointed out that individuals recently collected from tobacco warehouses may be slightly more resistant owing to an overwintering rest period denied those continuously reared in a laboratory.

RATE OF COOLING OF BALES AND HOGSHEADS OF TOBACCO

To make this work applicable to the control of insects under warehouse conditions it was necessary to determine the rate of cooling of commercial packages of unmanufactured tobacco as well as to determine the reactions of the insect in this special habitat. A series of experiments were therefore carried on to determine the length of time required for various types of commercial packages of unmanufactured tobacco to cool to low temperatures in a commercial cold storage.

Four bales of cigar tobacco and one hogshead were borrowed from tobacco companies at Richmond, Va. The bale of Connecticut shade wrapper was packed in a wooden crate measuring 15 by 33½ by 35½ inches. The bale of Puerto Rican long filler was wrapped in heavy paper and enclosed in a burlap case. The dimensions were 22 by 25½ by 32 inches. The bale of Florida shade wrapper was packed in a tight pasteboard carton measuring 13 by 33 by 34½ inches. The Wisconsin filler was in a wooden case so open that it offered little insulation to the bale. Its dimensions were 30 by 29 by 40 inches. The hogshead was 54 inches high and 48 inches in diameter and enclosed in a thin slat crate.

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[4] See footnote 3.

Temperature readings were obtained by means of thermocouples inserted in the various containers. These were made of no. 36 copper and constantin wire and were thoroughly varnished and dipped in rubber cement to waterproof them. A thermocouple was placed in the center of each bale or hogshead by first making a hole in the outside case or carton and inserting a steel spike three-eighths of an inch in diameter. After withdrawing this spike the thermocouple was easily inserted by looping it over the end of a slender steel rod and thrusting it into the bale to the required depth. The rod was then withdrawn leaving the thermocouple in the desired position. In the case of the hogshead a thermocouple was placed in the center, an-

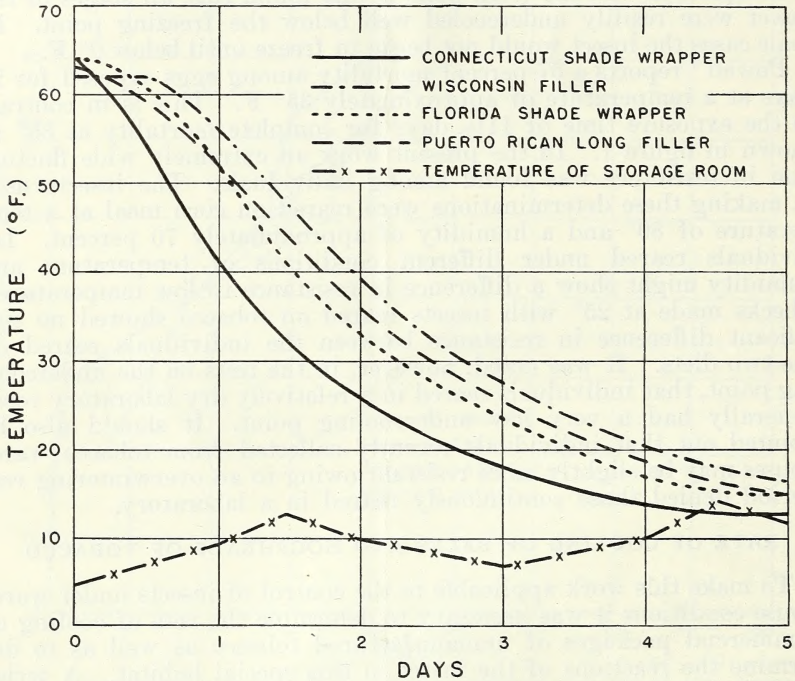

FIGURE 2.—Rate of cooling of the center of bales of four different types of cigar tobacco when placed in a cold room at 10° F.

other midway between the outside and the center, and a third one-fourth the distance to the center. Two couples each were placed in the four bales, one in the center and another midway between the outside and the center. The electromotive force was measured by means of a potentiometer and converted into degrees Fahrenheit. After installation of the thermocouples the tobacco was moved into a low-temperature room of the cold-storage plant which was maintained at an average temperature of 10° F. Figures 2 and 3 show the results obtained in this experiment. In order to simplify the graph the temperature reading for the center of the bales only is given in figure 2. The tobacco half way to the center of each bale cooled down from a half a day to a day more rapidly than the center, but otherwise the curve was much the same. The reading for the half-way point in the hogshead was left out of figure 3 for the same reason.

The temperature of the center of the bale of Connecticut shade wrapper fell from 64° to 15° F. in 3½ days. The outer reading in the same bale fell to 15° in 2½ days. The temperature at the center of the bale of Florida wrapper fell to 15° in 4½ days, that of the Wisconsin filler in 5½ days (not shown in figure 2), and that of the Puerto Rican long filler in 5 days. Fifteen days' exposure was required to bring the temperature of the center of the hogshead down to 15°, and 10 days was required for the point 6 inches from the outside.

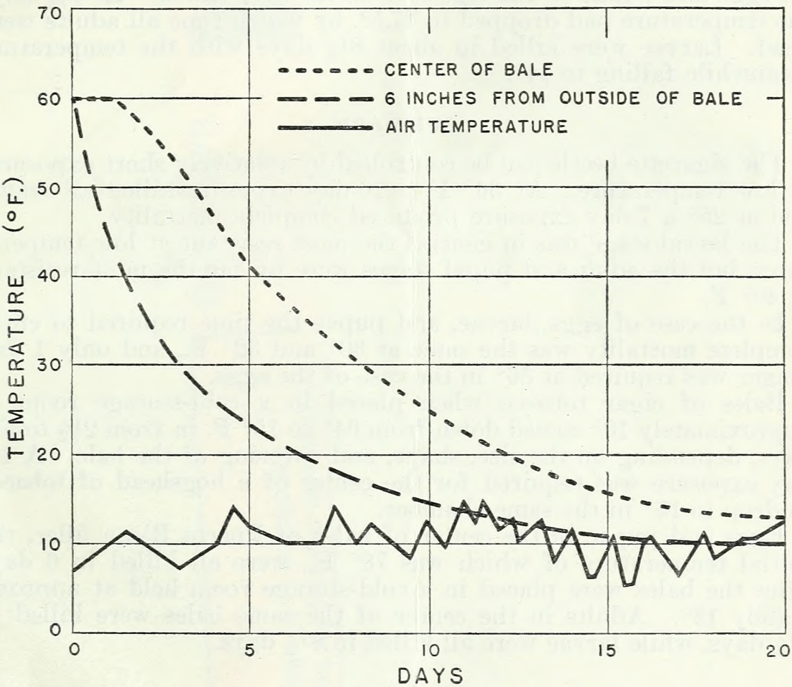

Figure 3.—Rate of cooling of the tobacco at the center and 6 inches from the outside of a hogshead when placed in a cold room at 10° F.

TREATMENT OF INFESTED BALES

Knowing the time required to kill exposed insects and the rate of cooling of bales and hogsheads, it is possible to estimate the exposure required to control all stages of the insect in normally infested bales. This was checked experimentally by exposing bales artificially infested with different stages of the insect, since no bales known to have sufficient infestation could be readily obtained. A supply of hollow spikes were constructed into which a number of insects could be placed and thrust into the tobacco to any required depth. These spikes were three-eighths of an inch in diameter and 22 inches long, 18 inches of the length being a maple handle. The remaining 4 inches was a hollow brass tubing perforated with small holes and headed up with a brass point which could be unscrewed to allow access to the interior of the tubing. A hundred insects were placed in the end of each spike, and the spikes were thrust into the centers of bales of Puerto Rican filler. A thermocouple was also placed in the center of each bale and the lot placed in a refrigerated room held at approximately 13° F. The wooden handle prevented undue conduction of heat from the bales. Although conditions were somewhat artificial, the results obtained checked very closely with the calculations. The temperature at the center of the bales was 78° at the start of the experiment and dropped to 18° in 6 days, in which time all eggs and pupae of the cigarette beetle were killed. In 6¼ days the temperature had dropped to 17.5°, by which time all adults were dead. Larvae were killed in about 8½ days with the temperature meanwhile falling to 14°.

SUMMARY

The cigarette beetle can be controlled by relatively short exposures to low temperature. At 36° F. a 16-day exposure killed all stages and at 25° a 7-day exposure produced complete mortality.

The larval stage was in general the most resistant at low temperatures, but the adult and pupal stages were by far the most resistant at 40° F.

In the case of eggs, larvae, and pupae the time required to effect complete mortality was the same at 30° and 32° F., and only 1 day longer was required at 36° in the case of the eggs.

Bales of cigar tobacco when placed in a cold-storage room at approximately 10° cooled down from 64° to 15° F. in from 2½ to 5½ days, depending on the size, shape, and covering of the bale. A 15-day exposure was required for the center of a hogshead of tobacco to drop to 15° in the same chamber.

Eggs and pupae in the center of bales of Puerto Rican filler, the initial temperature of which was 78° F., were all killed in 6 days after the bales were placed in a cold-storage room held at approximately 13°. Adults in the center of the same bales were killed in 6¼ days, while larvae were all killed in 8½ days.

U. S. GOVERNMENT PRINTING OFFICE: 1938

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